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REPORT 47/54

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Controlled Fragmentation XXXV. A Technique for the Study of the Cutting Action of Grooved Charges on Steel

T. W. Taylor
Safety in Mines Research Establishment, Buxton

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Controlled Fragmentation XXXV. A technique for the study of the cutting action of grooved charges on steel

by

T.W. Taylor, B.Sc.

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SUMMARY

Cylindrical charges with a longitudinal groove along one side were detonated in contact with a smooth steel block. A simple technique for measuring the depth of cut and deformation of the steel has been devised. It was possible to correlate the dimensions of the groove with the depth of cut obtained and the technique provides a simple means of comparing the efficiency of different shapes of groove.

1. INTRODUCTION

During the development of the grooved-charge method of controlling fragmentation the comparison of the effectiveness of groove profiles was carried out by comparing the fragmentation produced when the different profiles were used in similar charges in identical casings. Only experiments with V-shaped grooves have been reported.

This method is laborious and slow and is only indirect: numerical evaluation is not possible and extrapolation of the results to other circumstances is difficult. Moreover, comparison is only possible where the expected control is close to optimum for the casing.

In thick-walled casings it is not always possible to obtain the desired fragment size with V-shaped grooves since the base of the groove for optimum apex angle and depth becomes too large. It is possible that there is a more efficient shape of groove on a narrower base, and if this could be used the limiting fragment size for a given wall thickness would be reduced.

A simple and rapid technique for comparing the cutting action of different grooves was therefore desired. Such a method has now been devised and tested by comparing the cuts produced in steel blocks by various V-shaped grooves in a standard charge of H.E.

2. EXPERIMENTAL

2.1 Steel targets - The steel blocks used as targets consisted of short lengths cut from a round mild steel bar, 3¾-in. diameter with the ends smooth finished by surface grinding. Two thicknesses of block were used, viz., 3-in. for experiments E1, E2, E3 and D1 and 2-in. for the remainder. The blocks 2-in. thick were not split by the charges more than the 3-in. thick blocks and the measurements taken on both sizes did not differ significantly.

The blocks were thrown a considerable distance by the detonation of the charge but were not damaged appreciably.

2.2 Former for preparation of charges - To prepare the charges with a groove down one side a special cylindrical brass mould was made (Fig. 1). The mould was 3 in. long and 1 in. internal diameter and was divided longitudinally into two halves so that the cast charges could be more easily removed. A slot was milled in the wall part way along one section of the mould and a series of five interchangeable brass groove profiles were made which could be fitted into this slot as required. The details of the profiles used are shown in Table 1.

With the particular brass groove profiles used for these experiments the fit between the base of the profile and the inner wall of the mould was not always perfect. During casting of the charge a little explosive sometimes flowed between the two and when the charges were withdrawn this lip was broken and caused some chipping of the corner formed by the base of the groove and surface of the charge. Although the amount of chipping did not appear to affect the results obtained in these experiments it is clearly desirable to arrange as good a fit as possible between the groove profile and inner face of the mould.

2.3 Charge and initiation - The mould was greased slightly with vaseline and placed upright on a smooth glass plate: a cellophane filler-cap was fitted to the top. The charge was then cast in the normal way from 'cloudy' CE/TNT 30/70. Perfect charges were not easy to obtain and care was necessary when extracting the charges from the mould to avoid damage. Details of the weights of charges and condition of the groove corners are given in Table 2.

Detonation of the charge was obtained by means of a tetryl booster 1-in. diameter and 0.25-in. thick held in position at one end of the cylinder by means of a 1-in. diameter wooden plug and cellophane tape. The wooden plug was drilled centrally to take a No. 6 commercial detonator and thus hold it in position with the end in contact with the tetryl booster. A view of the complete charge in position on a target is shown in Fig. 2.

2.4 Reproduction of the cut - Direct measurement of the depth of cut in the block is not easy as it is necessary to section the block at many points across the cut or to obtain an accurately lined-up section along the length of the cut. It was therefore decided to obtain a reproduction, in relief, of the damage by casting a disk of Wood's metal on to the surface.

A length of cellophane was wrapped tightly round the periphery of the target and extended a little more than $\frac{1}{4}$ in. above the damaged surface. The target was then warmed on a hot-plate and molten Wood's metal poured over the damaged area to give a depth of about $\frac{1}{4}$ in. It is necessary to avoid over-heating of both target and Wood's metal as this causes blow-holes in the casting. Just before the Wood's metal sets two bolts were inserted to provide threaded holes which could be used for later removal of the casting.

When the metal had cooled, the excess cellophane standing proud of the Wood's metal was cut away, the bolts were withdrawn and the casting, still in position on the target, was faced up in a lathe. This ensured that the finished surface was as nearly as practicable parallel to the original surface of the target. The cellophane was then removed entirely and by replacing the two bolts the target and Wood's metal disk could be carefully separated.

With suitable care in casting it was found possible to obtain a good relief copy of the cut in the steel and measurements could be easily made using a micrometer and surface plate. A photograph of a typical disk is shown in Fig. 3.

2.5 Measurement of the cut - The flat face of the Wood's metal was placed on a surface plate and the height of various points in the relief were measured by means of a micrometer. There were two areas at the extreme edges of the block on either side of the cut which were not affected by the explosion. These areas on the relief therefore served as a reference level and the height of the relief above this indicated the depth of cut in the steel.

The position of the junction between the tetryl booster and main charge could be clearly seen on the relief. With this point as zero the height of the relief was measured at $\frac{1}{4}$-in. intervals along the ridge: the micrometer head was $\frac{1}{4}$-in. in diameter and hence the maximum depth of cut within each $\frac{1}{4}$-in. interval was obtained. The measurements for different profiles are given in Tables 3 to 6 and the results are summarized in Table 7.

Measurements were also taken of the deformation of the surface at the side of the cut and the width of the cut and from the composite measurements a section of the deformed surface can be built up. This is illustrated in Fig. 4 which shows the relevant measurements used to compare the efficiencies of different groove profiles.

3. DISCUSSION

From targets E1 and D1 repeat Wood's metal castings were made and measured. The measurements are included in Tables 3 to 5 and it appears that the variation between repeat castings is less than the variation

between repeat experiments. It is also clear from these results that the thickness of casting is not critical.

If the mechanism of cutting is considered, it seems likely that the cut d_2 is first produced in the block by the Munroe jet and at a slightly later stage there is the general deformation d_1 due to the proximity of the body of the charge. When different profiles are to be compared, therefore, chance variation between the strengths of different targets can be eliminated if the ratio d_2/d_1, which may be called the relative depth of cut, is considered and not the absolute depth of cut. The variation of this ratio with groove depth for the two angles used has been plotted in Fig. 5 and it appears that, for each angle, the relative depth of cut is directly proportional to the depth of groove in the charge. The proportionality differs for the two angles.

If grooves of different angles but equal widths of base are compared (experiments E, A and B, C in Table 7) it is seen that equal depths of cut were obtained.

4. APPENDIX

Table 1 - Dimensions of groove formers

Groove letter	Depth of groove, in.	Base of groove, in.	Apex angle of groove
E	0.226	0.257	59°12'
A	0.176	0.258	72°30'
B	0.171	0.194	59° 6'
C	0.133	0.196	72°54'
D	0.124	0.145	60°36'

Table 2 - Details of charges

Groove letter and expt. no.	Charge weight gram	Quality of edges of grooves
A1	59.8	Fair
A2	59.4	Good
A3	60.0	Rather poor
B1	60.2	Fair
B2	59.4	Good
B3	60.0	Good
C1		Fair
C2	61.0	Fair
C3	60.5	Fair
D1		
D2	60.9	Good
D3	60.8	Good

Table 3 - Measurements of relief (D): peak height of ridge above reference level, mils

Position along ridge, in.	Groove letter and experiment number															Repeat castings	
	E			A			B			C			D			E	D
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	1
0.25	117	107	113	133	110	108	103	107	114	101	105	100	93	91	102	107	87
0.50	109	105	97	118	106	103	90	84	100	95	107	97	93	90	99	104	86
0.75	117	119	107	113	109	102	91	85	98	92	103	91	89	91	94	114	84
1.00	119	122	112	119	104	100	91	95	94	96	111	93	90	92	93	121	83
1.25	129	118	112	121	104	111	99	102	101	92	108	94	92	97	95	124	86
1.50	130	117	113	111	107	110	103	100	106	106	102	95	95	92	95	128	90
1.75	122	126	117	109	110	111	102	94	115	101	106	106	95	90	94	120	99
2.00	128	117	115	107	107	117	99	102	105	102	101	106	98	93	92	126	98
2.25	132	118	122	105	101	120	105	97	103	108	114	99	99	99	98	128	93
2.50	134	121	128	114	116	134	107	98	95	112	113	103	98	98	86	130	96
2.75	140	121	129	113	110	132	112	96	94	93	103	103	97	95	85	134	90
Thickness of disk at two sides	182 184	339 340	281 283	206 205	246 251	269 270	224 212	243 249	296 295	238 236	218 217	236 235	279	346 341	290 280	196 198	249 249
Mean	125	117	115	115	108	113	100	96	102	100	107	99	94	93	94	121	90
Mean for each groove	119			112			99			102			94				
S.D. for each groove	9.1			8.6			7.3			5.9			3.9				

Table 4 - Measurement of relief (d_1): height of rim above reference level, mils

Position along ridge, in.	Groove letter and experiment number															Repeat castings	
	E			A			B			C			D			E	D
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	1
0.25	33	31	29	47	29	26	35	30	43	35	41	36	37	45	48	23	36
0.50	37	32	32	47	31	30	37	33	44	37	42	37	43	48	48	28	39
0.75	38	33	33	45	33	31	37	33	42	40	42	40	43	47	47	30	41
1.00	38	37	34	42	34	36	39	36	41	39	42	41	44	46	45	31	42
1.25	38	37	37	39	36	36	39	38	39	40	42	41	45	45	45	31	42
1.50	39	39	41	38	37	38	40	39	38	40	43	39	46	45	43	32	45
1.75	42	42	44	37	37	42	42	43	38	41	43	40	47	45	42	36	45
2.00	46	43	47	34	40	51	43	45	38	42	44	40	48	45	41	39	46
2.25	49	46	48	34	43	48	50	48	39	43	46	41	49	48	43	41	47
2.50	56	49	53	33	43	53	51	50	41	44	48	43	50	49	42	46	49
2.75	59	53	60	30	45	54	50	49	38	44	49	42	49	49	40	48	48
Mean	43	40	42	39	37	40	42	40	40	40	44	40	46	47	44	35	44

Table 5 - Measurement of relief (d_2): peak height of ridge above rim, mils

Position along ridge, in.	Groove letter and experiment number															Repeat castings	
	E			A			B			C			D			E	D
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	1
0.25	83	77	86	85	84	83	67	79	71	64	65	63	56	51	52	83	51
0.50	73	75	69	71	77	74	52	53	56	56	65	60	50	41	44	75	47
0.75	79	87	78	68	78	73	54	53	56	50	62	49	45	43	45	82	43
1.00	81	87	80	76	74	65	48	61	53	56	70	52	46	45	46	92	42
1.25	92	80	78	82	70	76	59	66	64	50	67	52	51	52	48	93	45
1.50	92	81	74	72	72	73	62	62	68	65	61	56	48	46	50	95	46
1.75	81	84	75	72	75	70	60	54	76	60	64	66	51	44	50	84	46
2.00	82	75	71	72	67	67	54	58	67	60	58	66	50	47	49	83	53
2.25	84	73	77	70	61	73	54	51	65	65	69	58	50	49	53	89	48
2.50	82	73	73	80	76	81	55	50	55	68	61	60	48	48	42	86	48
2.75	84	70	68	82	68	79	61	49	57	57	56	61	48	44	44	86	45
Mean	83	78	75	75	73	74	57	58	63	59	63	59	49	46	48	86	47
Mean for groove	79			74			59			60			48				
S.D. of Mean	6.2			5.8			7.6			5.7			3.5				

Table 6 - Measurement of widths: maximum width of ridge, mils

Position along ridge, in.	Groove letter and experiment number														
	E			A			B			C			D		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
0	138	126	130	122	114	110	106	118	110	94	94	134	63	83	87
0.50	102	118	110	114	110	106	102	110	94	90	90	78	75	75	75
1.00	142	126	122	114	102	94	114	98	90	87	94	78	90	87	79
1.50	122	114	130	102	90	118	110	106	118	83	83	90	98	67	90
2.00	110	138	122	98	90	106	83	90	110	83	79	78	83	79	75
2.50	106	106	122	138	90	118	90	98	90	94	98	78	67	75	71
Mean	120	121	123	115	99	109	101	103	102	89	90	87	79	78	79
Mean for groove	121			108			102			89			79		

Table 7 - Summary of results

Groove letter	Mean height d_1 mils	Mean height d_2 mils	Relative depth of cut d_2/d_1	Mean width of relief mils
E	42	79	1.88	121
A	39	74	1.89	108
B	41	59	1.43	102
C	41	60	1.46	89
D	46	48	1.04	79

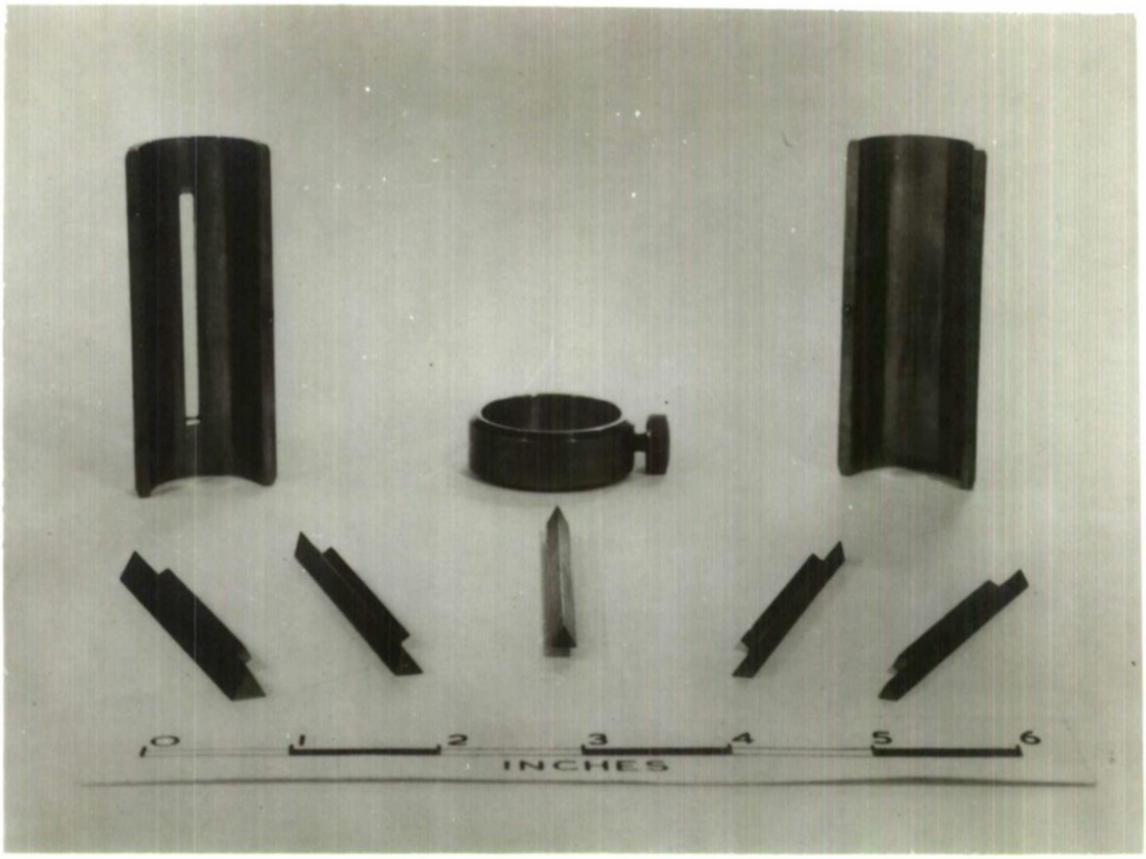

FIG. 1

Brass mould and groove formers

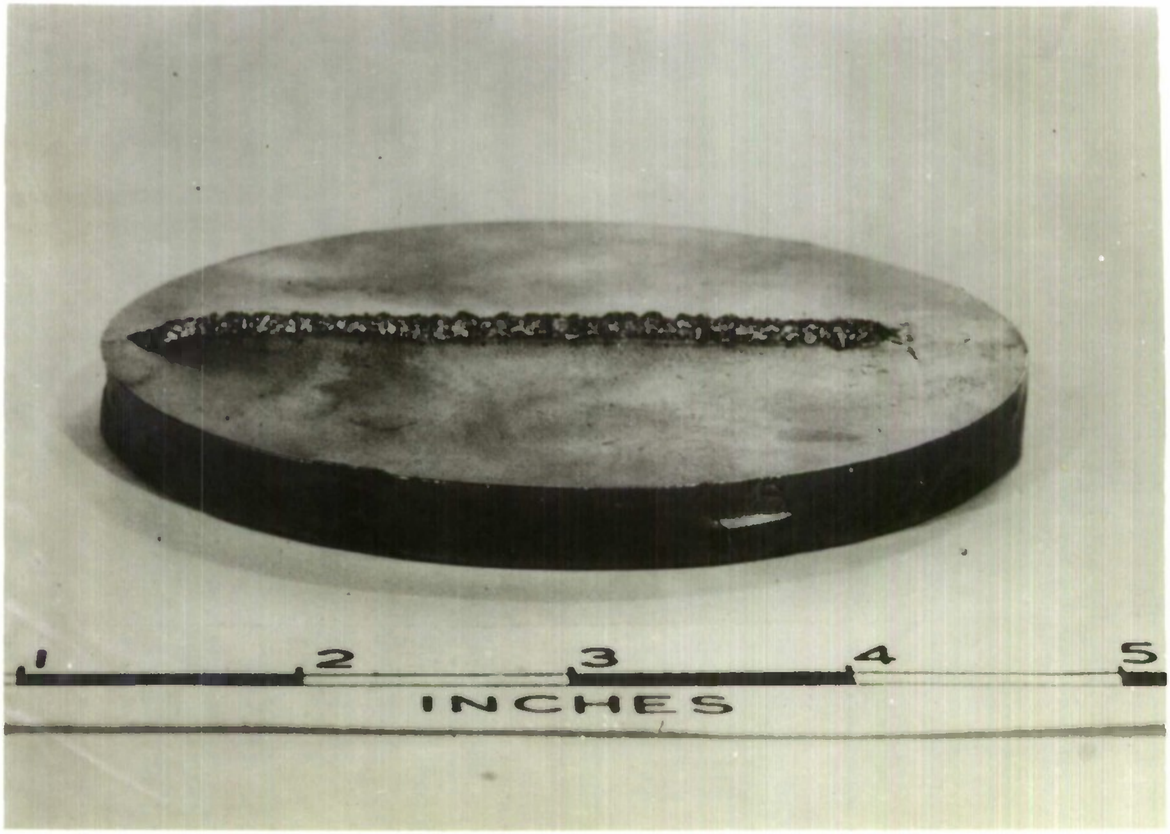

FIG. 3

View of cast Wood's metal disk

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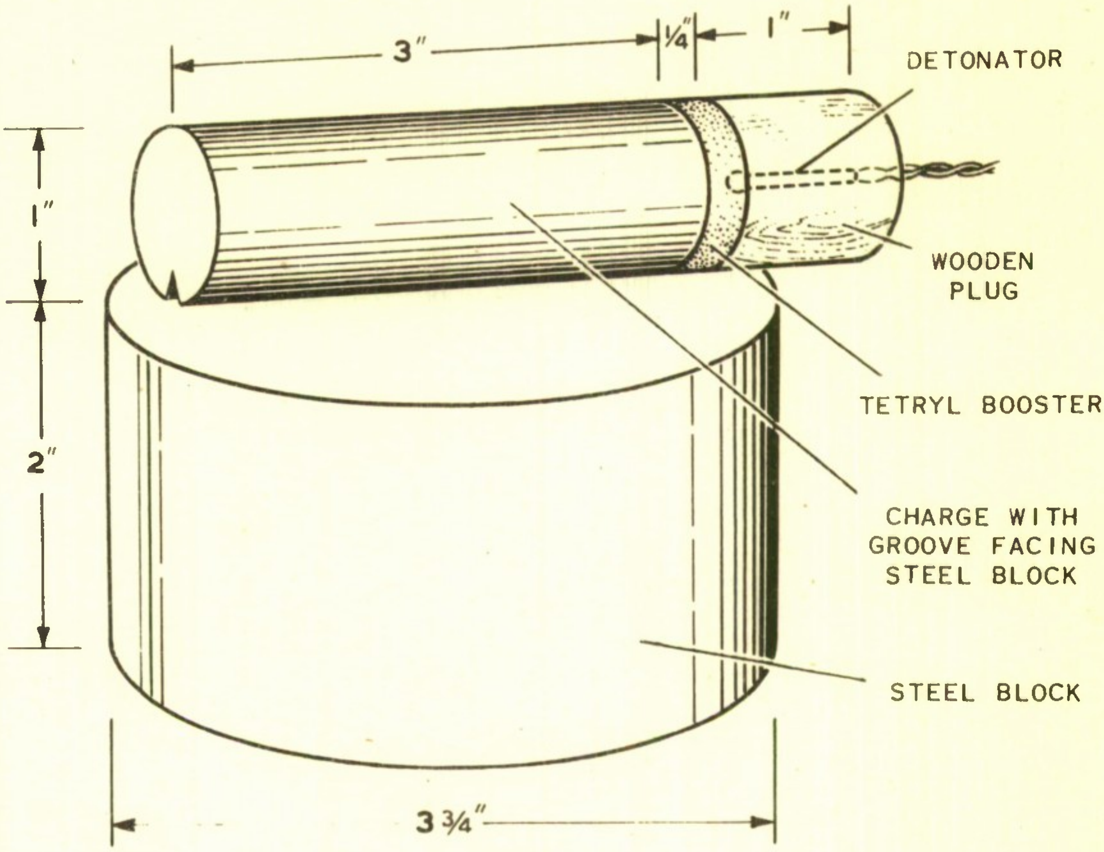
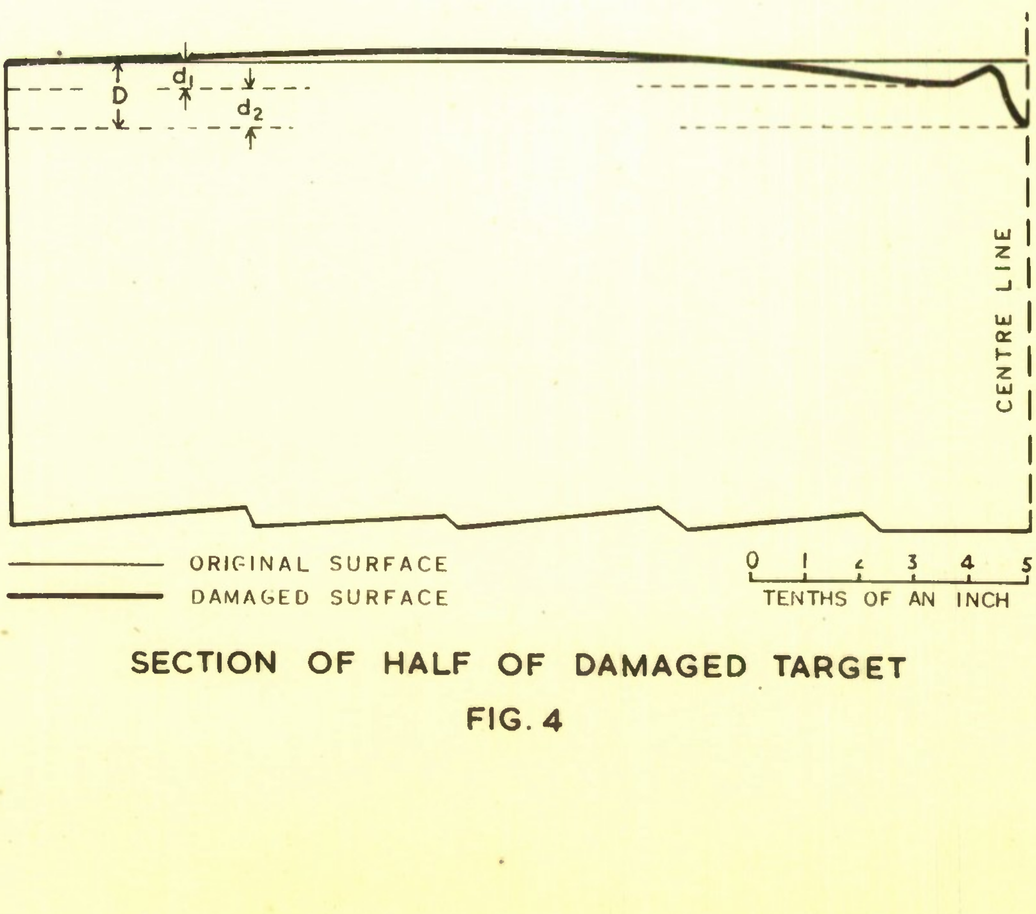


CHARGE IMMEDIATELY BEFORE DETONATION

FIG. 2



SECTION OF HALF OF DAMAGED TARGET

FIG. 4

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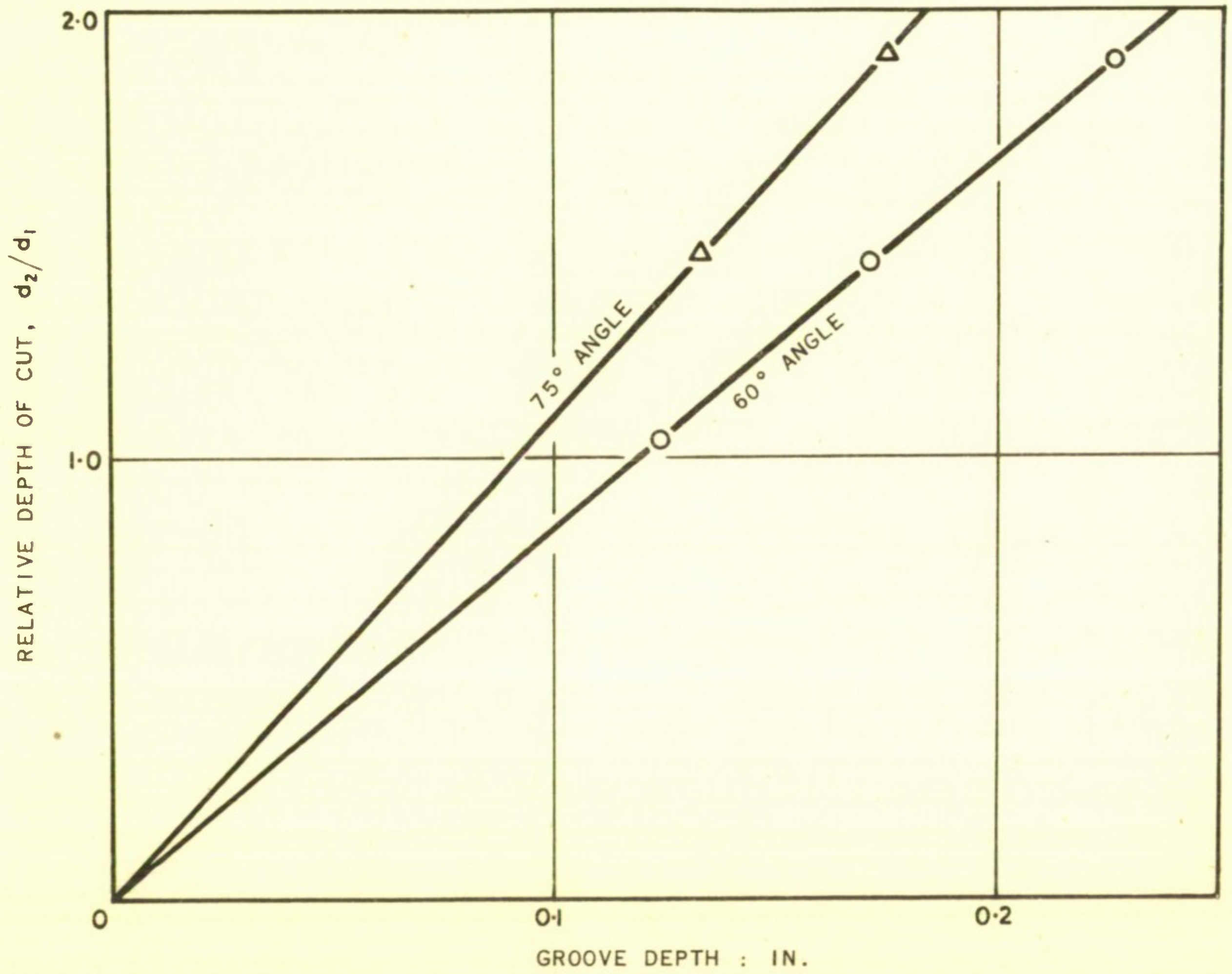

RELATION BETWEEN RELATIVE DEPTH OF CUT AND GROOVE DEPTH

FIG. 5

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